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Research paper

Is there a cannabis epidemic model? Evidence from France, Germany and USA

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ABSTRACT

Background: Cannabis is the most popular illicit drug in the world, but the process of its diffusion through the population has rarely been studied. The unfolding of the tobacco epidemic was accompanied by a shift in the educational gradient of users across generations. As a consequence, cannabis may show the same pattern of widening social inequalities. We test the diffusion hypotheses that a positive value in older cohorts – the more educated experimenting more – shifts to a negative one in younger cohorts – the more educated experimenting less, first for males and then females.
Methods: Three nationwide subsamples (18–64 years old) of representative surveys conducted in France (n = 21,818), Germany (n = 7887) and USA (n = 37,115) in 2009–2010 recorded age at cannabis experimentation (i.e., first use), educational level, gender, and age. Cumulative prevalence of experimentation was plotted for three retrospective cohorts (50–64, 35–49, 18–34 years old at data collection) and multivariate time-discrete logistic regression was computed by gender and generation to model age at experimentation adjusted on age at data collection and educational level. This latter was measured according to four categories derived from the International Standard Classification of Education (ISCED) and a relative (rather than absolute) index of education.
Results: The findings demonstrate a consistent pattern of evolution of the prevalence, gender ratio and educational gradient across generations and countries that support the hypothesis of an "epidemic" of cannabis experimentation that mimics the epidemic of tobacco.
Conclusion: We provide evidence for a cannabis epidemic model similar to the tobacco epidemic model. In the absence of clues regarding the future of cannabis use, our findings demonstrate that the gender gap is decreasing and, based on the epidemic model, suggest that we may expect widening social inequalities in cannabis experimentation if cannabis use decreases in the future.

Introduction

Cannabis is the most popular illegal drug used worldwide, and the USA is the country which has the highest level of use (EMCDDA, 2012). In Europe, as much as 23.7% of those aged 15–64 years old reported having smoked cannabis during their life (about 80.5 millions of people), 6.8% (23 millions) reported last year use, and 3.6% (12 millions) reported last month use (EMCDDA, 2012). There is a huge variation in the last year use prevalence across countries (from 0.4% to 14.3%). Past-year cannabis use has been shown to be highest in young adults and decreasing sharply in older ages in Europe and abroad (Vicente, Olszewski, & Matias, 2008). With regard to frequency of use, available data suggest that the majority of cannabis frequent users concentrate in individuals aged up to 35 years.

Cultivation of cannabis (or "hemp" or "marijuana") has been known for centuries in western countries, and used mainly for industrial purposes. In the USA, the use of cannabis as a psychoactive substance began in the middle of the 19th century, but

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recreational use of the drug became associated primarily with Mexican-American immigrant workers and the African-American jazz musician community in the beginning of the 20th century (Becker, 1963). It was recognized as an intoxicant in the late 1920s. The federal government voted the "Marihuana Tax Act" in 1937 that led to its interdiction (Peretti-Watel, Beck, & Legleye, 2007), but its use nevertheless became popular in the 1950s. Cannabis entered Europe as a medicine in the middle of the 19th century (Lords, 1998), but its recreational use was anecdotal before the late 1960s and limited to some small groups like "Le club des haschischins" (that comprised celebrities such as the poets Baudelaire and Theophile Gautier, the writers Balzac and Flaubert, and the painter Delacroix) in France (Gautier, 2011). The mass diffusion of cannabis began generally much later in the 1960s (although no statistical data source is available) and did not reach the same level as in the USA, but it generally started to be considered as a public health concern in the 1970s, at the same time as in the USA (Nahas & Greenwood, 1974).

In spite of these historical facts, quantitative data about the long-term history of cannabis use at the country level are scarce. The EMCDDA has produced several reports showing that lifetime prevalence in the adult population trended upward in many European countries during the 1990s until year 2005 (EMCDDA, 2011, p. 43), and the same pattern occurred as well in the adolescent population (Hibell et al., 2012, p. 13). But very few countries had reliable general population surveys on drug use before 1990 (Hartnoll, 1995), which led to public policies based on dubious statistics according to some researchers (Sutton & Maynard, 1993). The first general population surveys on cannabis use took place in the 1970s in Switzerland (Fahrenkrug, Rehm, Müller, Klingemann, & Linder, 1995), in 1975 in the USA (Volkow, 2005), in 1980 in Germany (Gesundheitsforschung, 1983), and in the 1990s in France (Beck, 2006). A chart of the evolution of cannabis use in the last 12 months among 15–34 year-olds in most European countries can be viewed on the EMCDDA website (http://www.emcdda.europa.eu/stats13). It is worth mentioning that some school surveys on drug use have been carried out earlier than the general population surveys (in Sweden, the first annual school survey by the Swedish Council for Information on Alcohol and other Drugs (CAN) took place in 1971: http://www.emcdda.europa.eu/publications/country-overviews/se).

In France, the proportion of lifetime users in the general population grew continuously from 13% in 1992 (first year of monitoring) to 33% in 2010 (Beck, Guignard, Richard, Tovar, & Spilka, 2011). In Germany, the 12-months prevalence among 18–24 year-old males increased from 7.4% in 1980 to 26% in 2003 and decreased thereafter to 17.5% in 2012. Similar trends were found for 25–39 year-olds but at a lower level (Kraus, Pabst, Piontek, & Gomes de Matos, 2013). In the USA, the proportion of young adults aged 18–25 who had ever used cannabis was 5.1% in 1965, but increased steadily to 54% in 1982. The lifetime use among 16–34 year-olds was estimated at 51.6% in 2010 (EMCDDA, 2011) while the lifetime prevalence among 12th graders was 48% in 1975, reached a first peak in 1979 (58%), and recently declined slightly (49% in 2012) (Johnston, O'Malley, Bachman, & Schulenberg, 2013).

In most cases, consumption remains experimental or occasional (Vicente et al., 2008). Particular patterns of use, however, were found to be associated with a range of adverse effects that can be categorized as acute, chronic or long-term, and the risk for developing problems is increased when initiation takes place early (Behrendt, Wittchen, Hofler, Lieb, & Beesdo, 2009; Chen, Storr, & Anthony, 2009; de Graaf et al., 2010; Fergusson & Horwood, 2006). An increasing prevalence of cannabis use may imply that the number of users experiencing adverse consequences on mental and physical health or on a social level will increase. Furthermore, cannabis use can lead to legal prosecution in many countries (even where alternatives to punishment are available for simple use).

Cannabis experimentation is relatively common but regular cannabis use is concentrated in the less affluent social groups: studies show that the lower social classes, the unemployed, and the least educated groups have a higher risk of becoming heavy cannabis users, although the experimentation may be a shared experience in all social groups. This disparity in regular use has been shown in the adolescent population (Korhonen et al., 2008; Legleye, Beck, Khlat, Peretti-Watel, & Chau, 2012; Mayet, Legleye, Chau, & Falissard, 2011) as well as in the adult population (Compton, Conway, Stinson, Colliver, & Grant, 2005; Legleye, Beck, Peretti-Watel, & Chau, 2008; Piontek, Kraus, Pabst, & Legleye, 2011). In France, the legal problems with cannabis are concentrated among the poorest groups of users who are visible and exposed to police activity, as shown by the comparison of police activity reports and data from the general population surveys (Obradovic, 2012; Peretti-Watel, Beck, & Legleye, 2004). The cannabis market changed recently with the development of home-grown cannabis in Europe (Ben Lakhdar & Weinberger, 2009; EMCDDA, 2008). This trend also induces a divide between people who can grow cannabis at home (that requires space and equipment) and avoid the problems related to cannabis purchase on the market (whether with the police or the dealers) and others. All these findings show that cannabis may contribute to social and health inequalities.

A problem in studying these inequalities comes from the lack of data regarding the association of socioeconomic status and cannabis use across generations. In contrast, since the seminal work by Lopez, Collishaw, and Piha (1994), a consequent literature has developed about the tobacco (mostly cigarette) epidemic in developed countries as well as in other parts of the world (Thun, Peto, Boreham, & Lopez, 2012). The tobacco epidemic conceptualizes variations in the age, educational and gender patterns in smoking behaviour (Lopez et al., 1994; Platt, Amos, Gnich, & Parry, 2003). It fits very well into the conceptual framework of the diffusion of innovations in societies (Rogers & Shoemaker, 1971): higher socioeconomic groups lead the way and lower socioeconomic groups follow. Following this pattern, smoking prevalence rises and declines first within the population groups that are at the forefront of experimentation and at the same time most sensitive to messages regarding the risks of tobacco. In the last stage, smoking is likely to become limited to the groups who adopted it relatively late in the diffusion process. Many European countries have reached the last stage of this epidemic and therefore display persistent or widening socioeconomic differences in relation to smoking at the same time declining prevalence of smoking occurs in the population as a whole (Huisman, Kunst, & Mackenbach, 2005). The literature shows a trend toward widening inequalities in cigarette smoking at this last stage of the epidemic in many developed countries (Federico, Costa, & Kunst, 2007; Harman, Graham, Francis, & Inskip, 2006; Legleye, Khlat, Beck, & Peretti-Watel, 2011; Smith, Frank, & Mustard, 2009) or at least a persistence of educational disparities (Pampel, 2009).

The comparison of cannabis and tobacco may not seem straightforward, since tobacco is a legal product and cannabis is not. There are nevertheless similarities. For decades, developed countries tried to fight tobacco consumption, and many specialists qualify tobacco as a denormalized or stigmatized product (Alamar & Glantz, 2006; Bayer, 2008; Chapman & Freeman, 2008; Peretti-Watel, Legleye, Guignard, & Beck, 2013; Peretti-Watel, Legleye, Guignard, & Beck, 2014). Due to the rise of cigarette prices, smuggling and black market activities increased (Ben Lakhdar, 2008; Guindon, Driezen, Chaloupka, & Fong, 2014). Additionally, cannabis users frequently mix cannabis with tobacco when smoking: this shared route of administration via inhalation may play an important role in the association of the two substances (Agrawal & Lynskey, 2009;

Agrawal, Madden, Bucholz, Heath, & Lynskey, 2008) and there is evidence that the use of one substance increases the risk of using the other (Mayet, Legleye, Chau, & Falissard, 2010; Mayet et al., 2011; Timberlake et al., 2007). In parallel, there are some changes in the regulation of cannabis, with 19 states and DC legalizing medical cannabis use and two states legalizing recreational use in the USA in the last years and an ongoing debate about depenalization of cannabis in the USA (C-SPAN, 2013) as well as in other countries like France and Switzerland. We are thus interested in the following questions: is there a process of change in cannabis use that is comparable to the tobacco epidemic? Do the social inequalities in cannabis smoking follow the same trend of a shifting educational gradient across generations? To answer these questions, we examine cross-national data from three countries that may be at different stages of a potential cannabis epidemic.

Data

The data come from three general population surveys: (1) the French Health Barometer 2010, a representative nationwide telephone survey of the non-institutionalized population aged 15–85 years (Beck et al., 2011), (2) the 2009 German Epidemiological Survey of Substance Abuse, a representative survey of the German-speaking non-institutionalized civilian population aged 18–64 years that uses a mixture of paper, telephone, and internet questionnaires (Kraus & Pabst, 2010) and (3) the 2010 U.S. National Survey of Drug Use and Health, a representative nationwide survey of individuals ages 12 years and older in the civilian, non-institutionalized population that combines CAPI (computer-assisted personal interviewing, in which the interviewer reads the questions) and ACASI (audio computer-assisted self-interviewing) (SAMSHA, 2011). For the population studied here, men and women at ages 18–64 years with completed education and cannabis experimentation data, the sample sizes equal 21,818 in France, 7887 in Germany and 37,005 in the United States.

In France, the survey used a two-stage simple random sample: household (with random digital dialling and including mobile and internet phones) and then one person within the household (Kish, 1949). The response rate was 60.5%. Weights adjust for survey design, non-response and the proportion of mobile phones, using a calibration process based on age, sex, diploma, employment status and region to match the distribution of the last national Labor Force Survey. In Germany, the survey used a two-stage probability sampling, first selecting communities proportional to population size and second selecting individuals from residents' registration office. The design over-sampled younger birth cohorts. The response rate was 50.1%. Weights adjust for the sampling design and the national distribution of age, gender, federal state, and size of the community.

In the United States, the survey used a stratified multistage procedure that oversamples youth and young adults. The response rate was 74.6%, and weights account for selection probability and non-response. Due to confidentiality concerns, the public use NSDUH data for the USA reports age in the following categories rather than the exact age: 18–20, 21–25, 26–34, 35–44, 45–49, and 50–64 years. These categories correspond to three broad age groups of 18–34, 35–49, and 50–64 years used in the analysis, but were recoded within the age groups to the midpoints of 19, 23, 30, 40, 47, and 57.

Statistical analysis

Measures

The outcome variable was age at first use of cannabis (i.e. age at experimentation). The independent variables were: gender, age at data collection, educational level, national citizenship and being native born. The categorization of educational level followed the International standard classification of education – ISCED – (UNESCO, 2005): (1) ISCED 0, 1, 2 (low): lower secondary education or less; (2) ISECD 3, 4 (medium): upper secondary education and post-secondary non-tertiary education; (3) ISECD 5B (high-short): first level of tertiary education; (4) ISCED 5A and over (high-long): tertiary education, upper level.

We chose education rather than occupation as an indicator of social position for the following reasons: (1) it is generally more accurately reported in survey questionnaires; (2) it is independent from workforce involvement, therefore available for both genders

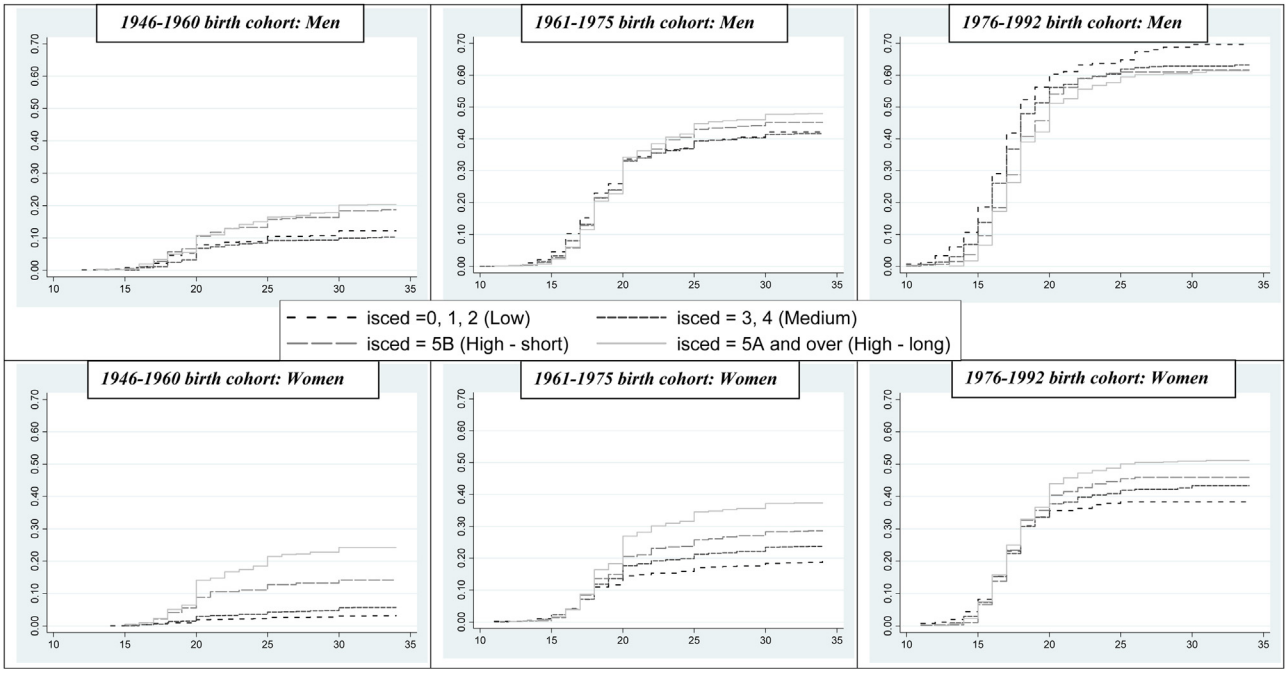

Fig. 1. Cumulative proportion of cannabis experimenters (*Y*-axis) according to age (*X*-axis) by sex, in three birth cohorts (France).

equally; (3) it is acquired early in life in most cases, more stable over the life course than occupation or income, and therefore less sensitive to the effects of selection mechanisms (Araya, Lewis, Rojas, & Fritsch, 2003); and (4) it is the most robust indicator for social position linked to tobacco smoking (Cutler & Lleras-Muney, 2010).

We considered one life period, from age 11 to current age at data collection or to age at cannabis experimentation (non-experimenters are censored) if these ages were below 35, as almost all experimentation (i.e. first uses) occurs before this limit (Vicente et al., 2008). Three birth cohorts were compared: 1936–1950, 1951–1975 and 1976–1992, i.e. people aged 18–34, 35–49 and 50–64 years at the time of data collection. Years of observation from age 11 until age of eventual experimentation will be called years of follow-up hereafter.

Data analysis

Cannabis experimentation patterns by cohort group and gender are described using 18 graphs focusing on the age span 11–34 years in Figs. 1–3: each presents the cumulative proportions of experimenters by age and educational levels for one country.

Table 1 presents the sociodemographic structure of each national sample. Multivariate time-discrete logistic regression (Allison, 2010) is used to model age at cannabis experimentation in each country, for each gender and birth cohort, with data for non-experimenters being right-censored (Tables 2–4). The covariates are: age at data collection, years of follow-up, years of follow-up squared (capturing the "S" shape of the curves in Figs. 1–3), and the ISCED-derived educational level.

As tracking the trends in educational gradients requires equivalent measures across age groups (Harman et al., 2006), we compute ridit scores (Bross, 1958) to produce a relative index of inequality (RII) for our ISCED-derived variable (Mackenbach & Kunst, 1997) in each cohort and for each gender separately, following (Hayes & Berry, 2002). The ridit assigns to each individual the proportion of the overall sample that has a higher education plus half of the proportion having the same educational level. The ridit is therefore a continuous (linearized) measure of relative education ranging from 0 to 1 (0 and 1 excluded) that takes into account the full distribution of education. Individuals in the lowest educational group (low) have the highest score, and individuals in the highest educational group (high-long) have the lowest score. The RII is the odds-ratio of the ridit. In order to provide more common measures of the effect of education, the classical OR of the lowest/highest educational group is also provided in the tables. Gender ratios for each educational level are estimated by computing odds ratios for the interaction between gender and ridit for educational level.

All analyses were carried out using SAS V9.3.2 and Stata V11.

Results

Table 1 shows that the prevalence of cannabis experimentation in the full sample is much higher in the USA (52.0%) than in France (32.8%) or Germany (27.9%). It is also almost stable in the USA across generation: it reaches 48.6% among 50–64 year-olds, 52.7% among 35–49 year-olds and 52.2% among 18–39 year-olds. By comparison, the prevalence in Germany and especially in France shows a very steep slope: from 13.2% in the oldest generation to 36.9% in the last generation in Germany and from 13.4% to 50.8% in France. In this latter country, the prevalence among men is even higher than in the USA (59.7% vs 56.2%). It also shows that the education level is higher in the USA than in France or Germany, except in the last generation in which the schooling process is not complete.

Figs. 1–3 show that in each country, the diffusion of cannabis experimentation follows an S-shaped curve for each gender and generation (this pattern is common to diffusion processes of

Table 1
Descriptive statistics of the samples.

	France			Germany			USA		
Response rate (%)	60.5			50.7			76.4		
	Men	Women	Total	Men	Women	Total	Men	Women	Total
Respondent sample size (18–64)	9866	11,952	21,818	3506	4381	7887	17,349	19,656	37,005
Cannabis experimentation: *n* (%)	3984 (40.4)	3168 (26.5)	7152 (32.8)	1161 (33.1)	1037 (23.7)	2198 (27.9)	9778 (56.4)	9465 (48.2)	19,243 (52.0)
50–64 years old	3125	4246	7371	874	1056	1930	1580	1929	3509
ISCED = 0, 1, 2 (Low): *n* (%)	822 (26.3)	1375 (32.4)	2197 (29.8)	58 (6.6)	125 (11.8)	183 (9.5)	229 (14.5)	229 (11.9)	458 (13.0)
ISCED = 3, 4 (Medium): *n* (%)	1407 (45.0)	1768 (41.6)	3175 (43.1)	394 (45.1)	598 (56.6)	992 (51.4)	502 (31.8)	615 (31.9)	1117 (31.8)
ISCED = 5B (High – short): *n* (%)	331 (10.6)	415 (9.8)	746 (10.1)	136 (15.6)	95 (9.0)	231 (12.0)	358 (22.7)	546 (28.3)	904 (25.8)
ISCED = 5A and over (High – long): *n* (%)	565 (18.1)	688 (16.2)	1253 (17.0)	286 (32.7)	238 (22.5)	524 (27.2)	491 (31.1)	539 (27.9)	1030 (29.4)
Cannabis experimentation: *n* (%)	510 (16.3)	475 (11.9)	985 (13.4)	154 (17.6)	100 (9.5)	254 (13.2)	882 (55.8)	824 (42.7)	1706 (48.6)
35–49 years old	3576	4100	7676	953	1191	2144	3822	4529	8351
ISCED = 0, 1, 2 (Low): *n* (%)	439 (12.3)	592 (14.4)	1031 (13.4)	42 (4.4)	79 (6.6)	121 (5.6)	506 (13.2)	560 (12.4)	1066 (12.8)
ISCED = 3, 4 (Medium): *n* (%)	1812 (50.7)	1887 (46.0)	3699 (48.2)	432 (45.3)	670 (56.3)	1102 (51.4)	1235 (32.3)	1271 (28.1)	2506 (30.0)
ISCED = 5B (High – short): *n* (%)	514 (14.4)	667 (16.3)	1181 (15.4)	177 (18.6)	123 (10.3)	300 (14.0)	906 (23.7)	1208 (26.7)	2114 (25.3)
ISCED = 5A and over (High – long): *n* (%)	811 (22.7)	954 (23.3)	1765 (23.0)	302 (31.7)	319 (26.8)	621 (29.0)	1175 (30.7)	1490 (32.9)	2665 (31.9)
Cannabis experimentation: *n* (%)	1585 (44.3)	1143 (27.9)	2728 (35.5)	286 (30.0)	251 (21.1)	537 (25.1)	2179 (57.0)	2219 (49.0)	4398 (52.7)
18–34 years old	3165	3606	6771	1679	2134	3813	11,947	13,198	25,145
ISCED = 0, 1, 2 (Low): *n* (%)	392 (12.4)	410 (11.4)	802 (11.8)	413 (24.6)	459 (21.5)	872 (22.8)	2276 (19.0)	2053 (15.6)	4329 (17.2)
ISCED = 3, 4 (Medium): *n* (%)	1676 (52.9)	1672 (46.4)	3348 (49.5)	938 (55.9)	1233 (57.8)	2171 (56.9)	4236 (35.5)	4228 (32.0)	8464 (33.7)
ISCED = 5B (High – short): *n* (%)	466 (14.7)	594 (16.5)	1060 (15.6)	105 (6.3)	111 (5.2)	216 (5.7)	3590 (30.0)	4332 (32.8)	7922 (31.5)
ISCED = 5A and over (High – long): *n* (%)	631 (19.9)	930 (25.8)	1561 (23.1)	223 (13.3)	331 (15.5)	554 (14.5)	1845 (15.4)	2585 (19.6)	4430 (17.6)
Cannabis experimentation: *n* (%)	1889 (59.7)	1550 (43.0)	3439 (50.8)	721 (42.9)	686 (32.2)	1407 (36.9)	6717 (56.2)	6422 (48.7)	13,139 (52.2)

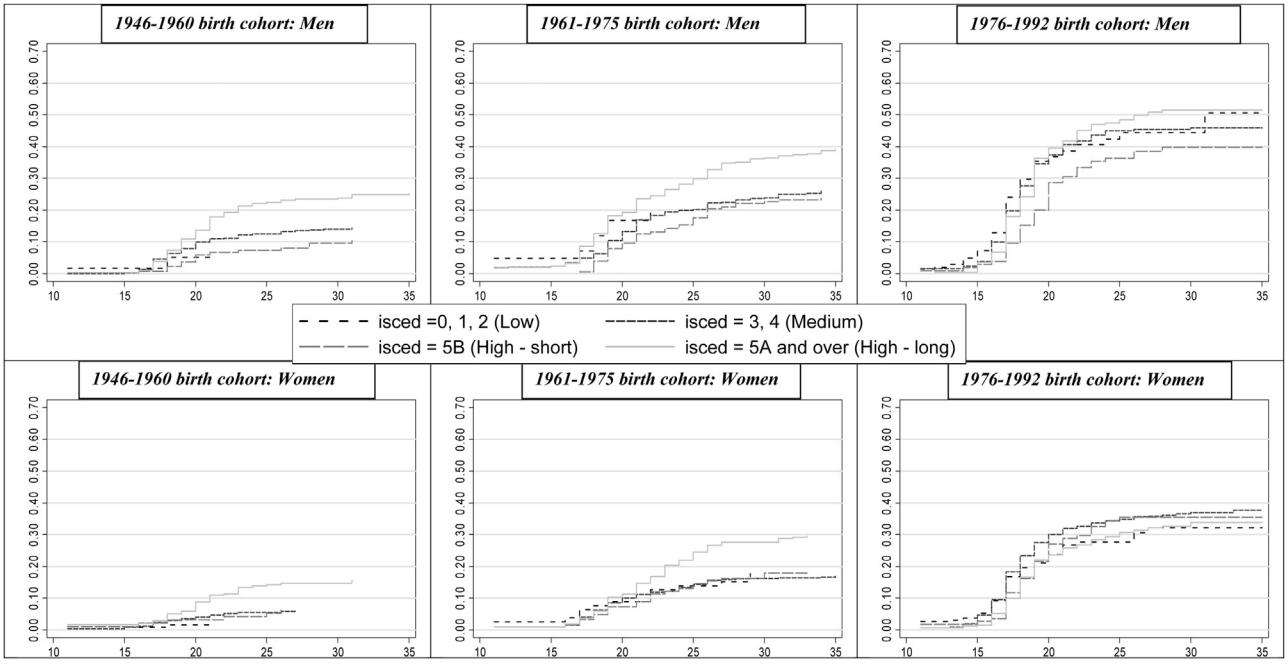

Fig. 2. Cumulative proportion of cannabis experimenters (*Y*-axis) according to age (*X*-axis) by sex, in three birth cohorts (Germany).

consumer goods). One first well-known result is that the cumulative proportion of experimenters is higher in males than in females at each age and that the proportion of experimenters increases across generations in each country. This is true for all educational levels and both genders, with the exception that experimentation shows a small decline between the oldest and the middle generations for the most educated in the USA. The second result is that in the older generation, the most educated people more often report cannabis experimentation than the least educated. On the contrary, in the middle generation and more markedly in the younger generation, this educational gradient tends to be reversed.

There are nevertheless differences across countries and genders. In each country, women are somewhat late in experimentation compared to men. In France, the reversal in educational gradient is complete among males in the younger generation whereas it is still incomplete among females. In the USA, the shift among males is more pronounced and even visible in the oldest generation: the most educated men were in the second upper position in the oldest generation, were already at the bottom (especially before age 25) in the middle generation and were clearly at the bottom in the youngest generation. The most educated women were on top in the oldest generation, still in the top curves in the middle generation and only slightly lower than the others in the youngest generation (especially before age 25). In Germany, the pattern is somewhat different since there is no shift in the educational gradient but a convergence of the curves: the most educated are always

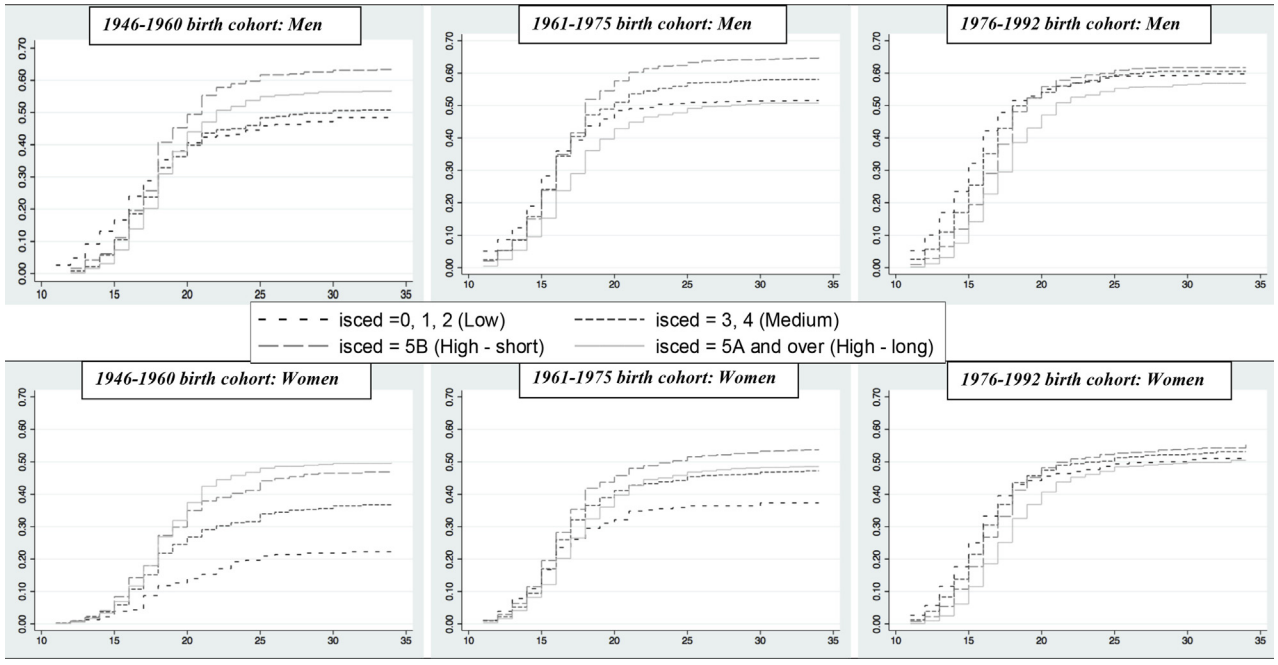

Fig. 3. Cumulative proportion of cannabis experimenters (*Y*-axis) according to age (*X*-axis) by sex, in three birth cohorts (USA).

Table 2
Time-discrete logistic regression of cannabis experimentation in France across generations (odds ratios and 95% confidence intervals).

	Men			Women			Gender ratio		
	OR	95%	CI	OR	95%	CI	OR	95%	CI
50–64 years old									
RII	**0.66**	0.46	0.94	**0.05**	0.03	0.09			
Age (in 2010)	**0.89**	0.87	0.91	**0.89**	0.87	0.91			
Follow-up	**1.84**	1.67	2.01	**1.96**	1.76	2.18			
Follow-up^2	**0.97**	0.97	0.98	**0.97**	0.97	0.98			
Men (ref = women)							**1.57**	1.37	1.81
Men × Ridit							**12.53**	6.37	24.65
OR (lowest/highest educ)	**0.57**	0.44	0.75	**0.12**	0.09	0.17			
35–49 years old									
RII	0.95	0.76	1.18	**0.41**	0.31	0.54			
Age (in 2010)	**0.95**	0.93	0.96	**0.96**	0.94	0.97			
Follow-up	**2.21**	2.09	2.34	**1.86**	1.75	1.97			
Follow-up^2	**0.96**	0.96	0.96	**0.97**	0.97	0.97			
Men							**1.85**	1.71	2.00
Men × Ridit							**2.26**	1.59	3.20
OR (lowest/highest educ)	0.95	0.79	1.14	**0.50**	0.40	0.62			
18–34 years old									
RII	**1.49**	1.23	1.80	**0.61**	0.48	0.77			
Age (in 2010)	**0.99**	0.98	1.00	**0.97**	0.96	0.98			
Follow-up	**2.91**	2.71	3.13	**3.21**	2.95	3.50			
Follow-up^2	**0.94**	0.93	0.94	**0.93**	0.93	0.94			
Men							**1.67**	1.56	1.79
Men × Ridit							**2.19**	1.62	2.96
OR (lowest/highest educ)	**1.41**	1.18	1.67	**0.70**	0.57	0.84			

on top, but the gap with the least educated tends to reduce across generations.

The multivariate analysis confirms these results. In the USA, there is a complete reversal in the educational gradient in men and women, while in France the reversal is only complete among men, and still on-going among women of the youngest generations. In France, cannabis experimentation is overwhelmingly concentrated among the most educated women in the older generation (RII = 0.05) and the RII for women is lower for each generation than the corresponding one for men, but also lower than the corresponding one in the USA. In the younger generation, cannabis experimentation is slightly concentrated among the least educated,

Table 3
Time-discrete logistic regression of cannabis experimentation in Germany across generations (odds ratios and 95% Confidence intervals).

	Men			Women			Gender ratio		
	OR	95%	CI	OR	95%	CI	OR	95%	CI
50–64 years old									
RII	**0.29**	0.15	0.57	**0.17**	0.07	0.42			
Age (in 2010)	**0.90**	0.86	0.94	**0.89**	0.84	0.94			
Follow-up	**2.06**	1.68	2.54	**1.61**	1.25	2.06			
Follow-up^2	**0.97**	0.96	0.98	**0.98**	0.97	0.99			
Men							**2.37**	1.79	3.14
Men × Ridit							1.78	0.59	5.36
OR (lowest/highest educ)	**0.25**	0.09	0.70	**0.23**	0.08	0.64			
35–49 years old									
RII	**0.43**	0.27	0.68	**0.40**	0.24	0.65			
Age (in 2010)	**0.95**	0.92	0.98	**0.93**	0.90	0.96			
Follow-up	**1.40**	1.25	1.56	**1.66**	1.44	1.91			
Follow-up^2	**0.99**	0.98	0.99	**0.98**	0.97	0.98			
Men							**1.57**	1.31	1.87
Men × Ridit							1.11	0.57	2.19
OR (lowest/highest educ)	0.49	0.27	1.06	0.57	0.32	1.05			
18–34 years old									
RII	1.05	0.74	1.49	1.06	0.73	1.54			
Age (in 2010)	1.00	0.97	1.01	0.99	0.98	1.01			
Follow-up	**2.61**	2.20	3.09	**2.02**	1.74	2.35			
Follow-up^2	**0.95**	0.94	0.96	**0.96**	0.95	0.97			
Men							**1.43**	1.29	1.58
Men × Ridit							1.03	0.67	1.58
OR (lowest/highest educ)	0.97	0.73	1.11	1.01	0.73	1.40			

Table 4
Time-discrete logistic regression of cannabis experimentation in the USA across generations (odds ratios and 95% Confidence intervals).

	Men			Women			Gender ratio		
	OR	95%	CI	OR	95%	CI	OR	95%	CI
50–64									
RII	**0.77**	0.60	0.99	**0.37**	0.29	0.49			
Age (in 2010)[a]									
Years of follow-up	**1.91**	1.78	2.05	**1.84**	1.71	1.98			
Years of follow-up^2	**0.96**	0.96	0.97	**0.97**	0.96	0.97			
Men (ref = women)							**1.53**	1.39	1.69
Men × Ridit							**2.09**	1.46	3.00
OR (lowest/highest educ)	0.87	0.69	1.09	**0.36**	0.26	0.48			
35–49									
RII	**1.24**	1.06	1.45	**0.78**	0.67	0.92			
Age (in 2010)[b]	**1.03**	1.02	1.05	**1.04**	1.02	1.05			
Years of follow-up	**1.60**	1.53	1.67	**1.54**	1.48	1.60			
Years of follow-up^2	**0.97**	0.97	0.97	**0.97**	0.97	0.97			
Men (ref = women)							**1.31**	1.23	1.39
Men × Ridit							**1.58**	1.27	1.98
OR (lowest/highest educ)	1.13	0.97	1.31	**0.73**	0.62	0.85			
18–34									
RII	**1.38**	1.26	1.51	**1.24**	1.13	1.36			
Age (in 2010)[c]	1.00	0.99	1.01	**0.99**	0.99	1.00			
Years of follow-up	**2.02**	1.95	2.09	**2.05**	1.98	2.13			
Years of follow-up^2	**0.95**	0.95	0.95	**0.95**	0.95	0.95			
Men (ref = women)							**1.25**	1.21	1.30
Men × Ridit							1.10	0.97	1.26
OR (lowest/highest educ)	**1.37**	1.26	1.50	**1.22**	1.10	1.32			

RII: relative index of inequality.
[a] Subjects coded to one age value: 57.
[b] Subjects coded to two age values: 40 or 47.
[c] Subjects coded to three age values: 19, 23, or 30.

without gender differences in the USA (RII = 1.38 among men, 1.24 among women), whereas in France, it is clearly concentrated in the least educated men (RII = 1.49) but still concentrated in the most educated women (RII = 0.61). The gender ratios decrease across generations in the USA (1.53, 1.31 and 1.25 in the younger one) while they tend to increase in France (1.57, 1.85 and 1.67 in the younger one). In the USA, cannabis experimentation is thus almost as common among women as among men, whereas it is still a predominantly male behaviour in France.

These interpretations are confirmed by the OR for the cross-product gender × ridit that compares the males to the females among the least educated group. In the USA, the difference between the least educated men and women declines slowly across generations to statistical insignificance in the younger generation (2.09, 1.58, 1.10) while it declines sharply between the older and the middle generation and remains stable after a while in France (12.53, 2.26, 2.19). The educational disparities are thus more pronounced among men than women in France.

In Germany, a similar but less pronounced pattern of shift in the educational gradient across generations is found, with a strict parallel evolution of the educational gradient in men and women, leading to an RII estimate in the younger generations not significantly different from 1 for both genders (RII = 1.1). The effects of education are similar for both genders in each generation, as confirmed by the non-significant values of the OR associated with the interaction variable. In this country, cannabis use involved experimentation by the most educated groups in the past, but experimentation is now relatively homogeneously spread in the youngest generation. In parallel, the gender ratio decreases continuously across generations, from 2.37 to 1.43. This latter trend is close to the one observed in the USA.

Discussion

Summary of findings

This study provides an insight into the dynamics of the diffusion of cannabis experimentation in three western countries (France, Germany, USA) through the use of random nationwide representative general population surveys collected in 2009–2010. We investigated three generations of men and women aged 18–34, 35–49, 50–64 years (born in 1945–1960, 1961–1975, 1976–1992). Considering the rise in educational levels over time, we used a synthetic measure of the educational gap by way of the ridit, and estimated gender ratios within the different cohorts. The analysis is based on the reported age at first cannabis use.

We found a complete reversal of the educational gradient across generations for men and women in the USA, but compared to men, the reversal is delayed by one generation among women. In Germany, there is a partial reversal of educational gradient, with parallel timing for both genders: in the most recent generation, for each gender, cannabis experimentation is equally shared by people of all educational levels. In France, the complete reversal of gradient among men is similar to the one observed in the USA, but only a partial one among women: in the most recent generation, cannabis experimentation among women is still more frequent among the most educated. Men are overrepresented among the experimenters in the three countries, but the patterns of evolution differ: in Germany and in the USA, there is a slow convergence between genders, while differences are stable and more pronounced in France.

These results provide support to the hypothesis of a cannabis epidemic that shares many features with the tobacco epidemic: it begins in the most educated groups and among men, with women

adopting later and reaching a lower level of prevalence. Following this model, France seems to be at an earlier stage of the cannabis epidemic compared to Germany and the USA, especially in regard to gender differences.

One major difference with the model of the tobacco epidemic is the prevalence of cannabis experimentation does not decline across generations, and does not decline among the most educated groups (except in the USA between the oldest and the middle generation). Instead, it rises continuously in males, females, and all educational levels. However, this does not mean that cannabis use is on the rise in the same proportion across groups. In fact, the evolution of the distribution of current cannabis use may follow and reinforce the trend towards the shift in educational gradient that we found for experimentation. Almost all studies in the drug field show that regular cannabis use (and more markedly intensive, problematic use including dependence) is more frequent among people with low socioeconomic status or low education. Despite the fact that cannabis experimentation may be more common in the affluent social backgrounds, adolescents from these families are less prone to become daily or problematic users than the others. Cannabis and tobacco are similar from this point of view in adolescent surveys (Legleye et al., 2012; Legleye, Janssen, Beck, Chau, & Khlat, 2011a), while tobacco is more and more concentrated among the poor in developed countries (Peretti-Watel, Seror, Constance, & Beck, 2009), However, these goods also share social utilities and are intentionally used to enhance some moments and interactions.

Additionally, we found that the slopes of the curves of cumulative experimentation were steeper in the youngest generation: the OR for the years of follow-up, which represents the mean increased risk of being an experimenter for one additional year of age, were higher in the youngest cohort than in the other two, providing evidence that experimentation started at a younger age in recent years.

Interpretation of the findings

That the highest prevalence of experimentation switches from high to low education may be related to the theory of innovation (Rogers & Shoemaker, 1971): one may think that the product may have lost its appeal because it became more and more popular across time. In other words, cannabis may have lost its power of distinction (Bourdieu, 1979). The initial leaders in cannabis use who were the most educated groups may thus have preferred to use other drugs or to endorse other habits or attributes of cultural leadership. But this switch may reflect a change in the perception of health hazard of cannabis use by the most educated, in accordance with what has been documented for tobacco. Indeed, the hazard of cannabis smoke has been studied more extensively in recent years and emphasized in prevention campaigns.

The consequence of this shift is a potential rise in inequalities related to cannabis use, with low-educated groups being more exposed to cannabis experimentation that may be followed by deleterious health and psychosocial consequences: increased risk of later abuse and transition to other drugs, psychosocial maladaptation in case of abuse, and possible long-term respiratory harm. But this depends on the trajectories of use, a topic that is beyond the scope of this work.

One question raised by our study relates to the interpretation of differences between countries. First, although starting at different levels of cannabis experimentation (with the USA showing a much higher prevalence than France and Germany over past decades), the trend of the association with educational level is similar in the three countries, with cannabis increasingly concentrated among the least educated groups. However, there are strong disparities in terms of gender ratios: the USA offers the most balanced situation, followed by Germany, whereas cannabis experimentation is still a male behaviour in France. This contrasts with the fact that in the recent generation, the prevalence of cannabis experimentation in France is as high as in the USA. The gender ratio is thus neither directly linked to the level of experimentation nor to the timing of the diffusion of experimentation, as France and Germany present similar prevalence rates for experimentation in the oldest cohort. It seems to be linked to the dynamic of diffusion, as cannabis experimentation is diffusing more rapidly in France than in Germany, while levels are stable in the USA over two generations. Using a terminology used in economics, the cannabis market may be far from equilibrium in France and, to a lesser extent, in Germany, compared to the USA. Things may change in the future, as the gender ratio for experimentation at age 16 in the latest 2011 ESPAD school survey (Hibell et al., 2012, p. 89) suggests that experimentation in France is very high but gender balanced (39% for both genders, with a gender ratio of 1.0), followed by the USA (38% for boys, 31% for girls with a gender ratio of 1.2) and Germany (24% and 15% respectively, with a gender ratio of 1.6).

Cannabis regulations differ between the three countries but despite national and regional differences, the results of this study point out that prevention campaigns should focus on the most vulnerable part of the population, either to prevent experimentation, or more likely, to prevent transitions into more intensive use. The results also emphasize that at-risks groups vary with the stage of the diffusion process, as found for the tobacco epidemic.

That this pattern of diffusion may apply to other illicit drugs like cocaine and heroin and may not be restricted to smokable psychoactive products raises a question for future investigations. The addictive potential of recreational use may provide different results for different drugs. This study nevertheless suggests that, despite different legal status, cannabis and tobacco share some features in their diffusion across generations and social groups.

Comparison with other studies

This is the first cross-national study using this methodology and one of the few assessing the long-term evolution of cannabis use across populations, gender and educational groups. Recent publications on cannabis diffusion used different methodologies and were only conducted in the USA (Kerr, Greenfield, Bond, Ye, & Rehm, 2007; Miech & Koester, 2012) and Germany (Piontek et al., 2011). They neither focused on educational differences nor offered such a long retrospective time frame.

Limitations

Limitations of the findings relate to the cross-sectional data. First, the self-reported retrospective measures of age of experimentation may be biased by recall error. Although retrospective measures are generally found to be reliable for tobacco (Kenkel, Lillard, & Mathios, 2003) and cannabis (Johnson & Mott, 2001; Labouvie, Bates, & Pandina, 1997), differences in recall by age could affect the cohort comparisons and more specifically the least educated groups and ethnic minorities (Johnson & Mott, 2001). Second, the cross-sectional nature of the data makes it hard to disentangle the causal relationships between education and experimentation. Many youths experiment with cannabis before completing their education, requiring longitudinal data to draw causal conclusions about the relationship. It is clear, however, that the association is strong and has changed in meaningful ways. Third, the cross-sectional samples of the populations at older ages exclude those who died at younger ages, a group disproportionately composed of smokers and those with less education. Although differential mortality may bias comparisons to the oldest cohort, limiting the analysis to persons under age 65 years minimizes the problem. Fourth, the present data cannot separate the

independent influence of age, period, and cohort. Analyses of these effects require combined consecutive cross-sectional surveys.

Fifth, the sample size of the German data was limited, in addition to the limited number of experimenters in the older cohorts. Since cannabis use emerged later in East Germany than in West Germany, especially among older cohorts, it may lower the combined prevalence. However this does not alter the overall pattern of change across generations. In the USA, the exact age of the individuals was unknown. However, the confidence intervals are relatively narrow and the OR for the influence of age was very small in all three countries, suggesting that these limitations had only a small effect on the reliability of the results.

Finally, although differences in survey designs and data collection modes may have influenced comparisons between national prevalence, the national patterns of evolution of cannabis use likely are not affected by this potential bias. Additionally, differences in prevalence levels between the USA, France and Germany are confirmed by the results of recent school surveys (Hibell et al., 2012).

Compared to the age of onset of regular cigarette smoking that has been studied in a similar way, cannabis experimentation may not be followed by regular use. We cannot interpret our results as a description of cannabis use but rather as a description of the diffusion of cannabis as a product in the population. However, as noted above, initiation and particularly early initiation is an important predictor of future intensive use. The present data do not allow any projection of future cannabis use by cohort. We could only infer the future development of use by education based on the epidemiological model assuming a declining trend. But the patterns of use of cannabis and the similarity between tobacco and cannabis could change substantially with legalization of cannabis. In the United States, 19 states and DC have approved medical cannabis programs, and two states (Colorado and Washington) have legalized cannabis for recreational use. The change in legal status of the drug could increase prevalence level and reshape the educational gradient in cannabis use.

Future research is needed to study the evolution of the transition to regular use of cannabis across generations.

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